Intake, Site, and Extent of Nutrient Digestion of Lactating Cows Grazing Pasture

P. BERZAGHI,[1] J. H. HERBEIN, and C. E. POLAN
Department of Dairy Science, Virginia Agricultural Experiment Station, College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University, Blacksburg 24061-0315

ABSTRACT

The objective of this study was to determine intake and site and extent of nutrient digestion of lactating cows grazing pasture with or without energy supplementation. Four dual-cannulated (rumen and proximal duodenum) cows were randomly assigned to two groups to graze mixed cool season grass legume pasture with either no supplement or with 6.4 kg of cracked corn and mineral mix daily in a switchback design with three 2-wk periods. Markers (Cr_2O_3 and Co-EDTA) were used to estimate intake, duodenal flow, fecal output, and fractional rates of passage from the rumen. Daily OM intake was similar between diets, but OM intake of pasture was lower when cows were fed corn. Apparent OM and NDF digestibilities in the rumen and total digestive tract were lower when cows were supplemented with corn than when they consumed pasture only. Supplemental corn decreased ruminal NH_3 N (22 vs. 17 mg/dl) and increased N recovery at the duodenum (86% vs. 75% of N intake). Nonammonia, nonmicrobial N flowing to the duodenum was 67% of the total NAN flow. Corn increased energy intake of grazing cows, but decreased herbage intake and digestibility.
(**Key words**: pasture, ruminal turnover, ruminal nitrogen, microbial nitrogen flow)

Abbreviation key: **DLP** = duodenal liquid phase, **DPP** = duodenal particulate phase, **FO** = fecal output, **IVOMD** = in vitro OM digestibility, **NANMN** = nonammonia nonmicrobial N.

INTRODUCTION

Research efforts in dairy nutrition have been directed mainly toward increasing productivity of milk, milk fat, and milk protein. In the past few years, however, stagnation in milk prices combined with higher feed costs have reduced the economic margin for dairy producers. Effective utilization of available pasture has the potential to reduce feed costs, but very little research concerning pasture utilization for milk production in the US has been conducted until recently (16, 24). Most of the available information on grazing intake is from studies conducted in other countries (3, 6, 15, 21, 22), much of it from studies of growing steers. To improve the efficiency of milk production with grazing, information on nutrient utilization is needed. For example, well-managed pasture may provide a highly digestible, highly palatable forage with high N content that can support milk production at 25 kg/d under optimal conditions (19). However, there is little information concerning ruminal fermentation and nutrient flow in grazing cows in the US. Corn is utilized primarily as an energy supplement to enhance milk production, but the effects of corn on digestion of pasture by grazing cows have not been thoroughly evaluated. The objective of the present study was to evaluate nutrient digestion and flow in grazing lactating dairy cows with and without corn supplementation.

MATERIALS AND METHODS

Experimental Design and Cows

The experiment consisted of three 2-wk periods arranged in a switchback design in which the third period was a replication of the first. There were two diets: pasture alone and pasture supplemented daily with 6.4 kg of 95% cracked corn and 5% vitamin and mineral mix (16.0% Ca, 6.5% P, 5.8% Cl, 3.5% K, 3.2% S, 2.2% Mg, 1325 ppm of Zn, 1100 ppm of Mn, 265 ppm of Fe, 132 ppm of Cu, 5 ppm of Se, 3 ppm of Co, 2 ppm of I, 110,000 IU/kg of vitamin A, 44,000 IU/kg of vitamin D_3, and 550 IU/kg of vitamin E). Half of the daily allotment of supplement was fed after each milking (0100 and 1300 h). Four multiparous Holstein cows [554 ± 49 kg of BW ($\bar{X}$ ± SD) and 130 ± 25 DIM] with ruminal and proximal duodenal (T-shaped) cannulas were permitted to adapt to pasture

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[1]Current address: Department of Animal Science, University of Padova, Padova, Italy.

for 3 wk before the experiment began. All cows received 6.4 kg of the corn and vitamin and mineral mix daily during adaptation. Cows then were randomly assigned to one of the two dietary groups. At the beginning of the second period, one cow was replaced by a similar dual-cannulated cow that was previously adapted to grazing. Body weights were recorded after the 1300-h milking on the first and last day of each period. A nonlactating, ruminally cannulated cow was allowed to graze with the other cows to obtain representative pasture samples during grazing.

Pasture

The study was conducted during June and July 1991. The permanent pasture was divided into four paddocks of approximately 2.3 ha each. Pasture was managed under a rotational stocking scheme in which each paddock was occupied for approximately 7 d but varied in days to ensure an abundance of palatable forages. The cannulated cows were added to a group of 24 lactating Holstein cows that began grazing in April. Because of the dry weather during June and July, lagoon water was irrigated onto paddocks following each rotation.

Pastures were visually evaluated for botanical composition according to the method of Brodie (8) as modified by Abaye (1). On d 7 (0700 h) of each period, ruminal contents of the nonlactating cow were totally removed. The cow was then allowed to graze for 15 to 30 min, and grass masticates were collected from the cardia region of the rumen and stored at –20°C. After sample collection, the rumen was refilled with the original contents.

Markers

Chromium oxide and Co-EDTA were used as particulate and liquid markers, respectively. The Co-EDTA was prepared according to the procedure of Udén et al. (31). A solution of Co-EDTA was made prior to the study by dissolving Co-EDTA crystals in distilled water (62.5 g/L). From d 1 through 10 of each period, 7.5 g of Cr_2O_3 and 120 ml of Co-EDTA solution (7.5 g of Co-EDTA) were administered at 12-h intervals (1100 and 2300 h) through the ruminal cannula. Single doses of Cr_2O_3 were weighed into small paper bags. After the top three-fourths of the bag were sheared free, the Cr_2O_3 was evenly distributed onto the surface of the ruminal contents; then, the two portions of paper bag were left in the rumen.

Sampling and Storage

Milk production was recorded at each milking during the three periods. Milk samples were taken from each milking on d 11 and analyzed separately. Milk composition was determined based on weighted means of the a.m. and p.m. milkings. Duodenal and fecal samples were collected on d 7 (1000 h), d 8 (0200 and 1800 h), d 9 (0600 and 2200 h), and d 10 (1400 h). Duodenal digesta (1.5 L) were mixed thoroughly prior to obtaining two 270-ml samples, which were stored at –20°C. A large volume was needed to ensure representative sampling and to provide sufficient DM from the liquid phase for several analytical measures that are described subsequently. Feces, obtained by grab sampling, were stored in plastic bags at –20°C.

At the end of each period, whole duodenal and fecal samples were thawed at room temperature, mixed, and composited by cow. Approximately 800 ml of whole duodenal composite were refrozen, stored at –20°C, and kept in reserve. The remainder of the digesta was centrifuged at 3000 × *g* at 3 to 5°C for 10 min to obtain duodenal particulate (**DPP**) and duodenal liquid phases (**DLP**). Particulate, liquid, and fecal composites were then refrozen at –20°C.

Duodenal digesta also were sampled to determine marker depletion at 2, 4, 8, 12, 18, 24, 30, 36, 48, 60, 72, and 96 h after the last dose. Samples were lyophilized and ground through a 1-mm screen and then stored in a sealed container. At 0500 h on d 11, ruminal fluid (2 L) was collected via the ruminal cannula and placed in ice. The pH of ruminal fluid was determined with a pH meter within 30 min. Subsamples (5 ml) were preserved with either 1 ml of 20% orthophosphoric acid for determination of NH_3 N or 1 ml of internal standard (7 μmol/ml of isocaproic acid) for VFA analysis and then stored at –20°C. Ruminal bacteria were isolated from the remaining ruminal fluid by centrifugation at 200 × *g* at 3 to 5°C for 10 min to remove protozoa and feed particles, followed by centrifugation at 35,000 × *g* for 20 min to form a bacterial pellet. The pellet was resuspended in deionized water, recentrifuged twice, and then stored at –20°C. Corn samples were collected weekly and composited across periods.

Laboratory Analyses and Calculations

Fat and protein contents of milk were determined by infrared spectrometry (Multispec Mark I®; Foss Food Technology, Eden Plains, MN) in the Blue Ridge DHIA Laboratory (Blacksburg, VA). Composited pasture, DPP, and fecal samples were lyophi-

lized and then ground through a 1-mm screen in a cyclone mill (U. D. Corp., Boulder, CO). Composited DLP samples and bacterial isolates were lyophilized and then ground with a mortar and pestle. Organic matter was determined by ashing at 600°C in a muffle furnace for 6 h. The Kjeldahl method (4) was used for N analysis. The NDF and ADF were determined by the procedure of Van Soest et al. (33). In vitro OM digestibility (**IVOMD**) of five replicates of each pasture sample was determined by the procedure described by Goering and Van Soest (13) using ruminal fluid obtained from a cannulated grazing cow.

Fecal and digesta samples were wet ashed with nitric, perchloric, and sulfuric acids and hydrogen peroxide (29). Marker (Cr and Co) concentrations were determined by atomic absorption spectrophotometry (Varian Instruments, Palo Alto, CA). Ruminal fluid and whole duodenal digesta for ammonia analysis were centrifuged at 3000 × *g* for 10 min to remove particulate matter and then filtered through a 0.45-μm Metricel filter (Gelman Sciences, Inc., Ann Arbor, MI). Ammonia concentrations in ruminal fluid and duodenal digesta were determined according to the procedure described by Weatherburn (38). Ruminal VFA concentrations were measured by gas chromatography (Varian Vista 6000; Varian Instruments), using a glass column packed with 10% SP-1200, 1% H_3PO_4 liquid phase on 80/100 Chromasorb W AW packing (Supelco Inc., Bellefonte, PA). The column temperature was 125°C.

Microbial contribution to OM and N flow at the duodenum was calculated using cytosine as the microbial marker (7). Ruminal bacteria and duodenal liquid and particulate phases were analyzed for cytosine by HPLC (28). Technique modifications were similar to those described by Zerbini and Polan (39), except that a dry bath was used with mixing at 10-min intervals, and 0.2 *M* ammonium phosphate buffer was the diluent for the hydrolyzed solution. Microbial N as a percentage of total duodenal N flow was estimated for DLP and DPP using the ratio of cytosine to N in ruminal bacteria. Fecal concentration of Cr was used to calculate daily fecal output (**FO**). Contribution of the herbage to FO was estimated by subtracting the indigestible fraction of corn from total FO. Corn digestibility was assumed to be 67%, as reported by Tyrrell and Reynolds (30). Herbage intake was calculated by dividing the FO from herbage by the percentage of indigestible OM in herbage determined by IVOMD. Based on the two-marker technique, OM flow at the duodenum was calculated using the method of Armentano and Russell (2). Apparent OM and N digestibilities in the rumen were corrected for microbial contribution to calculate true OM and N digestibilities. Nonammonia N at the duodenum was calculated by subtracting NH_3 N flow from total N flow. Flow of nonammonia nonmicrobial N (**NANMN**) was determined by subtracting microbial flow from NAN. Liquid turnover rate was determined by fitting the descending portion of the Co depletion curve for whole duodenal digesta with a one-compartment exponential model (12) using the Marquardt method of the nonlinear regression procedure of SAS (26).

Statistics

All results were subjected to ANOVA by using the Type III sums of squares of the general linear models procedure of SAS (26). The data for the cow that was replaced after period 1 were discarded; thus, ANOVA was performed using 11 records. The data were analyzed with the following model:

$$Y_{ijk} = \mu + A_i + B_j + C_k + e_{ijk}$$

where

Y_{ijk} = dependent variables,
μ = overall mean,
A_i = effect of diet i (i = 1, 2),
B_j = effect of period j (j = 1, 2, 3),
C_k = effect of cow k (k = 1, 2, 3, 4), and
e_{ijk} = residual error (0, s^2).

Differences were considered to be significant at $P < 0.10$. All results are reported as least squares means.

Validation Trial

The validity of the technique that was used to estimate herbage intake was established in a subsequent trial using two lactating cows that were similar in size (606 kg of BW) and milk production (18 kg/d) and equipped with ruminal and duodenal cannulas. The cows were adapted to grazing for 2 wk and then placed in tie stalls for 14 d, during which time they were fed chopped grass that was harvested daily (1030 h) and stored in plastic cans at –20°C. The grass was thawed, weighed, sampled, and fed for ad libitum consumption at 0200, 0800, 1400, and 2000 h daily. Following milking at 0130 and 1330 h, cows were fed 4.5 kg of the corn and vitamin and mineral mix as previously described. Orts were recorded after each meal before fresh grass was fed. Orts were collected, weighed, and sampled at 1200 h. Grass and ort samples were dried at 70°C for 48 h. Administration

TABLE 1. Actual and estimated OM daily intake by cows fed fresh grass and corn in the validation trial.

Cow	Actual	Estimated	Estimated
(no.)	(kg)		(% of actual)
1855	6.8	6.5	95.5
2261	7.2	7.9	109.5
X			102.5
SD			7.0

of markers, days of sampling, sampling sequence, analytical procedures, and calculations of fecal OM output and OM intake were as described previously.

RESULTS AND DISCUSSION

Validation Trial

The actual and estimated intakes of OM are shown in Table 1. Mean estimates approximated actual consumption.

Botanical and Chemical Composition of Pasture

Tall fescue (*Festuca arundinacea*) was the dominant species of the pasture during the first two periods. Pastures also contained medium and ladino white clovers (*Trifolium repens*), ladino (*T. repens* cv. *Ladino*), bluegrass (*Poa pratensis*), and orchardgrass (*Dactylis glomerata*) in abundance and were consumed in the first two periods. Tall fescue was available in abundance, but was not consumed. Grasses were prevalent in the third period; orchardgrass and bluegrass were the principal grasses consumed. Because different paddocks were used for the three experimental periods, differences in botanical composition were attributed to differences among paddocks. To maintain high forage intake, cows were moved to a new paddock with abundant quantities of palatable forages rather than being forced to graze fescue.

The CP content of the forage ranged from 22 to 28% across the three periods (Table 2). The CP content was highest during the third period. Considering the botanical composition, a greater CP content of the forage was expected in the first two periods, when cows grazed the paddocks with abundant legumes. However, pastures were periodically irrigated with lagoon liquid during the trial, which might have increased the N content in the soil, causing an accumulation of N in the plant tissues. The NDF content of the forage was similar in the first two periods but appeared greater in the third. However, ADF was similar across periods. The IVOMD was approximately 70%; the value for the first period was slightly higher. Because the pastures were maintained in an actively growing state, the fiber content was higher than expected. The cell-wall content was higher, and the IVOMD was lower, than values reported by Hoffman et al. (16) for pastures in Pennsylvania that were principally orchardgrass with lesser amounts of smooth bromegrass. Mean maximum temperatures during the trial were 27 and 30°C for June and July, respectively, and the high temperature might have caused the greater fiber content of the herbage (32).

Ruminal Parameters

Ruminal pH, VFA, and NH_3 N are shown in Table 3. Ruminal fluid pH tended to be lower ($P < 0.14$) when corn was fed (6.2 vs. 6.4), but the difference was small. Concentration of VFA was similar for both diets and averaged 149 mmol/L. For cows grazing perennial ryegrass that was supplemented daily with either 1 or 7 kg/d of an energy concentrate, VFA concentration varied between 110 and 160 mmol/L (34). Concentration of VFA in this study was higher than that normally observed for cows fed drylot diets, indicating extensive fermentation of fresh grass. Molar percentages of acetate, butyrate, isobutyrate, isovalerate, and valerate did not differ between diets. Propionate was increased when cows were fed corn, resulting in a lower ratio of acetate to propionate. These changes were expected, considering that propionate is the major end product of starch fermentation.

Supplemental corn decreased NH_3 N (17.1 vs. 22.4 mg/dl), but concentrations were well above the 5 mg/dl necessary to maximize microbial growth as indicated by Satter and Slyter (27). Elevated concentrations of ruminal NH_3 N are common when cows are fed fresh grass from temperate climates (5). For cows

TABLE 2. Chemical composition and in vitro OM digestibility (IVOMD) of the herbage and corn supplement.[1]

Item	Period 1	Period 2	Period 3	Corn
	(% of OM)			
CP	24.5	22.6	28.3	9.3
NDF	61.1	58.7	68.1	8.7
ADF	36.1	40.9	37.6	2.7
IVOMD	74.1	69.5	70.5	67.0[2]

[1]Values are means of five replicates.

[2]In vivo digestibility (30).

TABLE 3. Ruminal pH, VFA, NH_3 N, and ruminal turnover in response to grazing pasture with or without 6.4 kg/d of a corn and vitamin and mineral supplement.

Item	Pasture		Pasture plus corn		$P <$
	$\bar{X}$	SE	$\bar{X}$	SE	
Observations, no.	6		5		
pH	6.4	<0.1	6.2	<0.1	0.14
VFA, mmol/L	150	3	148	4	0.74
Acetate (A), mol/100 ml	63.2	0.5	62.4	0.5	0.41
Propionate (P), mol/100 mol	18.7	0.1	19.1	0.1	0.08
Isobutyrate, mol/100 mol	1.4	0.1	1.3	0.1	0.24
Butyrate, mol/100 mol	12.9	0.7	13.5	0.8	0.60
Isovalerate, mol/100 mol	2.1	<0.1	2.2	<0.1	0.26
Valerate, mol/100 mol	1.7	0.1	1.5	0.1	0.20
A:P	3.4	<0.1	3.3	<0.1	0.01
NH_3 N, mg/dl	22.4	1.6	17.1	1.7	0.10
Fractional passage rates, %/h					
Particle	7.5	0.4	7.1	0.4	0.58
Liquid	18.2	0.5	18.5	0.6	0.68

grazing fresh ryegrass (36), ruminal NH_3 N peaked at 30 mg/dl when 1 kg of an energy concentrate was supplemented daily and at 20 mg/dl when 7 kg of concentrate were supplemented. Supplementation of pasture with concentrate might have resulted in lower ruminal NH_3 N concentration because microbial growth was stimulated, as was observed in this study and the study by van Vuuren et al. (36, 37). In addition, lower NH_3 N concentration could be expected because of the lower herbage intake when cows were supplemented with corn (Table 4), which resulted in a marked change (~25%) in the ratio of N to OM.

Rates of ruminal liquid or particle passage were not affected by the supplement (Table 3). Similar rates for liquids have been reported for grazing cows (17, 35). Liquid passage rates for grazing cows were greater than those determined for cows fed diets based on silage or hay, usually <10%/h (14, 25). In the study by Holden et al. (17), pasture, hay, and silage exceeded 10%. Considering the correlation between liquid and particle passage rate (11), a faster turnover of particles, as observed, would be expected for the grazing cow than for cows on drylot feeding.

However, as an indicator, Cr_2O_3 may separate from feed particles and partially flow with the liquid phase, which would bias particle rate of passage, tending to overestimate it. However, our results for the particle rate of passage agreed with results of van Vuuren et al. (34), who reported that the rate of

TABLE 4. Organic matter intake, flow to the duodenum, and digestibility in response to grazing pasture with or without 6.4 kg/d of a corn and vitamin and mineral supplement.

Item	Pasture		Pasture plus corn		$P <$
	$\bar{X}$	SE	$\bar{X}$	SE	
Observations, no.	6		5		
Intake					
Pasture, kg/d	13.0	0.8	9.8	0.9	0.07
Corn, kg/d	0.0	. . .	5.4	. . .	. . .
Total, kg/d	13.0	0.8	15.2	0.9	0.16
Total, % of BW	2.4	0.1	2.8	0.1	0.18
Flow to the duodenum					
Total, kg/d	6.6	0.3	8.6	0.4	0.02
Digestibility					
Total tract, %	71.9	0.5	69.9	0.6	0.08
Rumen, apparent, %	48.9	1.6	43.3	1.7	0.09
Rumen, true, %	64.3	1.3	58.7	1.4	0.06
Rumen, % of total tract	68.1	2.5	62.3	2.7	0.21

TABLE 5. Intake of NDF, flow to the duodenum, and digestibility in response to grazing pasture with or without 6.4 kg/d of a corn and vitamin and mineral supplement.

Item	Pasture		Pasture plus corn		$P <$
	$\bar{X}$	SE	$\bar{X}$	SE	
Observations, no.	6		5		
Intake, kg/d	7.4	0.5	6.2	0.6	0.17
Flow to duodenum, kg/d	2.7	0.1	2.8	0.1	0.74
Digestibility					
Total tract, %	70.4	1.0	64.5	1.1	0.02
Rumen, %	62.0	2.5	53.6	2.7	0.09
Rumen, % of total tract	88.1	2.9	82.6	3.2	0.24

passage of Cr-mordanted fiber was 6.7%/h in lactating cows grazing pasture.

OM Intake, Flow, and Digestion

Herbage OM intake was lower (9.8 vs. 13 kg/d) for cows consuming corn plus pasture than for cows consuming pasture alone (Table 4). However, total OM intake, expressed as kilograms per day or as a percentage of BW, was similar for cows fed the pasture and for those fed pasture plus corn. Pasture intake in this study was less than that reported for supplemented or unsupplemented lactating cows grazing pasture (3, 22). Although herbage composition might have played an important role, intake probably was depressed by the high environmental temperatures. Shading was not available, except at midday when cows were brought in for approximately 3 h for feeding and milking. When energy concentrates were offered to grazing cows, herbage intake commonly decreased (21). Substitution rate (decrease in forage intake per unit of supplement) was 0.59 in this study, which was within the range (0.39 to 0.64) reported by Meijs (21) for lactating cows grazing pasture.

The application of a previously reported (30) digestion coefficient for corn (67%), which was lower than the mean IVOMD of the herbage (72%), may explain the lower values for whole tract OM digestibility of pasture supplemented with corn. Organic matter apparently and truly digested in the rumen also was lower for the supplemented diet. The percentage of OM digested in the rumen was similar for the pasture diet plus corn (62.3%) and pasture alone (68.1%) in this study. van Vuuren et al. (37) reported greater ruminal digestion of OM of cows receiving fresh ryegrass only than of those supplemented with a concentrate based on corn. However, apparent total tract digestibility in their study was similar, suggesting that site of digestion might have shifted from the rumen to the duodenum because of the greater passage of undigested starch.

van Vuuren et al. (37) also observed an increase in NDF flow, indicating that fiber disappearance in the rumen was reduced by the presence of corn in the diet. This result agrees with the results of our study, which indicated that ruminal and total tract disappearance of NDF were significantly reduced for cows fed pasture supplemented with corn (Table 5). The difference in ruminal pH (6.4 vs. 6.2) was not an explanation. The presence of the readily degradable carbohydrate of corn in the rumen might have altered the microbial population and limited the activity of cellulolytic bacteria (23), causing the decease in ruminal digestibility of NDF and OM. Because voluntary intake by grazing animals is directly correlated with diet digestibility (15), the decrease in herbage intake can be attributed to the detrimental effect of corn on ruminal digestion of fresh grass. Meijs (22) reported higher herbage intake and milk production by grazing cows receiving fibrous rather than starchy supplements; therefore, grazing cows may benefit from concentrates that interfere less with fermentation of fresh grass in the rumen.

N Intake, Flow, and Digestion

Intake, duodenal flow, and digestibility of N are reported in Table 6. Nitrogen intake was lower for cows supplemented with corn than for those fed pasture alone. However, total N intake was not different. There were no significant differences in total NAN, microbial N, or NANMN flows at the duodenum. As for OM, total tract digestibility was higher for cows fed pasture than for cows fed the pasture supplemented with corn.

The NANMN, expressed as a percentage of N intake, averaged 25.5% and was not different between diets, indicating that about 74% of herbage protein

was degraded in the rumen. These data were not corrected for endogenous secretions; therefore, more than 74% of protein was probably degraded. Beever and Siddons (6) worked with steers grazing perennial ryegrass or white clover and reported that N degradation of feed varied from 64 to 87% with a mean of 75 and 79%, respectively, for grass and legumes. Cammell et al. (10) estimated herbage N degradability to be 90% for grazing steers. In situ data indicate that more than 90% of N compounds in fresh grass are potentially degradable and that degradation rate may vary from 10 to 20%/h (5, 35).

Intake N recovered at the duodenum was about 12 percentage units greater for the supplemented diet (87% vs. 75%). Because temperate pastures are high in N content and in degradability, losses of N in the rumen as NH_3 are likely to occur. With sheep fed either ruani (*Lolium perenne* L.) or manawa (*Lolium multiflorum Lam* × *L. perenne L.*), ryegrass, or white clover, N losses in the rumen were 31, 11, and 22%, respectively (5). When ryegrass and white clover were fed in different proportions to lactating cows, N losses varied from 14 to 21% (5). Nitrogen losses in our study varied between 8 and 35% among cows and were in agreement with the values found in the literature. The losses were lower when pasture was supplemented with corn and were associated with a lower NH_3 N concentration in the rumen (Table 3). Energy supplementation possibly modified N kinetics in the rumen because energy supplements may reduce rate of forage degradation (32), thus decreasing release of N and reducing NH_3 N accumulation in the rumen. More likely, additional N is being used for microbial protein production when available energy is provided. Ruminal NH_3 N was decreased when starch was supplemented to a dairy cow diet based on alfalfa haylage and corn silage (9). The lower NH_3 N was associated with increased dietary protein flow to the duodenum, which implies a reduction of CP degradation in the rumen. In our study, however, NANMN was similar between diets, suggesting that rate of N degradation in the rumen was unchanged.

Differences in the recovery of duodenal N can be partially explained by microbial N flow, which was 30 g/d higher for cows grazing pasture and supplemented with corn than for cows grazing pasture alone (Table 7). Nitrogen supply to the duodenum was largely dependent on microbial N, which represented 65 to 69% of the NAN flow. Efficiency of microbial synthesis was similar, whether expressed as OM apparently ($\bar{X}$ = 40 g/kg) or truly ($\bar{X}$ = 30 g/kg) digested, but approximately 600 g/d more OM was truly digested

TABLE 6. Nitrogen intake, duodenal flow, and digestibility in response to grazing pasture with or without 6.4 kg/d of a corn and vitamin and mineral supplement.

Item	Pasture		Pasture plus corn		$P <$
	$\bar{X}$	SE	$\bar{X}$	SE	
Observations, no.	6		5		
Intake					
Pasture, g/d	522	37	391	40	0.09
Corn, g/d	0		80		
Total, g/d	522	37	471	40	0.42
Flow to duodenum					
Total, g/d	386	14	408	15	0.40
NAN, g/d	371	14	396	15	0.32
Microbial, g/d	243	14	273	15	0.23
Microbial, % of	65.2	2.0	69.1	2.1	0.28
NAN					
NANMN,[1] g/d	128	7	123	8	0.68
NANMN, % of Intake	24.9	2.1	26.2	2.3	0.70
EMPSAD[2]	38.6	2.6	40.4	2.9	0.40
EMPSTD[3]	29.0	1.4	31.0	1.6	0.42
Digestibility					
Total tract, %	78.8	1.0	71.9	1.1	0.01
Duodenal recovery, %	75.3	3.5	86.7	3.9	0.09

[1]Nonammonia, nonmicrobial N.

[2]Efficiency of microbial protein synthesis in grams of N per kilogram of OM apparently digested in the rumen.

[3]Efficiency of microbial protein synthesis in grams of N per kilogram of OM truly digested in the rumen.

TABLE 7. Production and composition of milk in response to grazing pasture with or without 6.4 kg/d of a corn and vitamin and mineral supplement.

Item	Pasture		Pasture plus corn		$P <$
	$\bar{X}$	SE	$\bar{X}$	SE	
Observations, no.	6		5		
Milk, kg/d	19.5	0.6	23.7	0.6	0.01
Fat					
g/d	710	25	770	26	0.19
%	3.69	0.09	3.25	0.09	0.04
Protein					
g/d	550	22	680	24	0.03
%	2.84	0.01	2.84	0.01	0.88

when cows consumed the supplemented diet. Therefore, the slight increase in microbial flow may be attributed to the higher amount of OM digested in the rumen. Because of the high ruminal degradability of fresh grass and the dependence on microbial N to supply CP to the small intestine, grazing dairy cows may benefit from supplemental RUP, even if fresh grass contains greater amounts of N.

Milk Production and Composition

Production difference was not an important goal of this study. However, production and composition of milk provided evidence of the nutritional and physiological status of the cow. Passage rates, intake, and digestibility are more applicable for high producing cows. Milk production was 4.2 kg/d greater when cows grazed pasture and received the corn supplement than when they grazed pasture alone (Table 7). Milk production increased 0.65 kg/kg of supplement, despite the reduction in herbage intake. Leaver et al. (20) summarized several trials with grazing cows producing 14 to 18 kg/d of milk. Those researchers reported a mean increase in milk production of 0.32 kg/kg of concentrate. Journet and Demarquilly (19) found that cows producing 25 kg/d responded with 0.4 kg of milk/kg of supplement.

Despite the greater milk output when corn was fed, fat yield was similar because of lower fat percentage. A previous report (24) indicated a depression of milk fat content because of corn supplementation, and the depression was even greater when amounts of corn were higher. This effect may be associated with the lower ratio of acetate to propionate in the rumen (Table 3). Corn supplementation did not affect milk protein content; therefore, the greater protein yield directly reflects the difference in milk production. However, in other research (18), milk protein percentage increased as concentrate intake increased, which was probably due to additional energy intake.

CONCLUSIONS

Herbage protein was subjected to extensive ruminal fermentation, which resulted in increased ruminal NH_3 N concentration and N losses in the rumen. Ruminal liquid turnover was much greater than that reported for diets based on silage or hay. Nitrogen flow to the duodenum was mainly microbial N, indicating vast ruminal microbial synthesis, but also suggesting the potential for production response to supplements providing balanced RUP. Corn supplementation reduced ruminal NH_3 N concentration and increased recovery of intake N at the duodenum, but total tract digestibility was lower when corn was fed. More research is needed to evaluate the effect of energy supplements, including fibrous concentrates, RUP source, or ruminally protected fats, which can utilize feed efficiently and maintain milk production in diets prone to high N losses and fast rates of passage as occur in grazing cows.

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